Human Performance Modeling of Approach and Landing Operations: A Concept Examination of Synthetic Vision Systems

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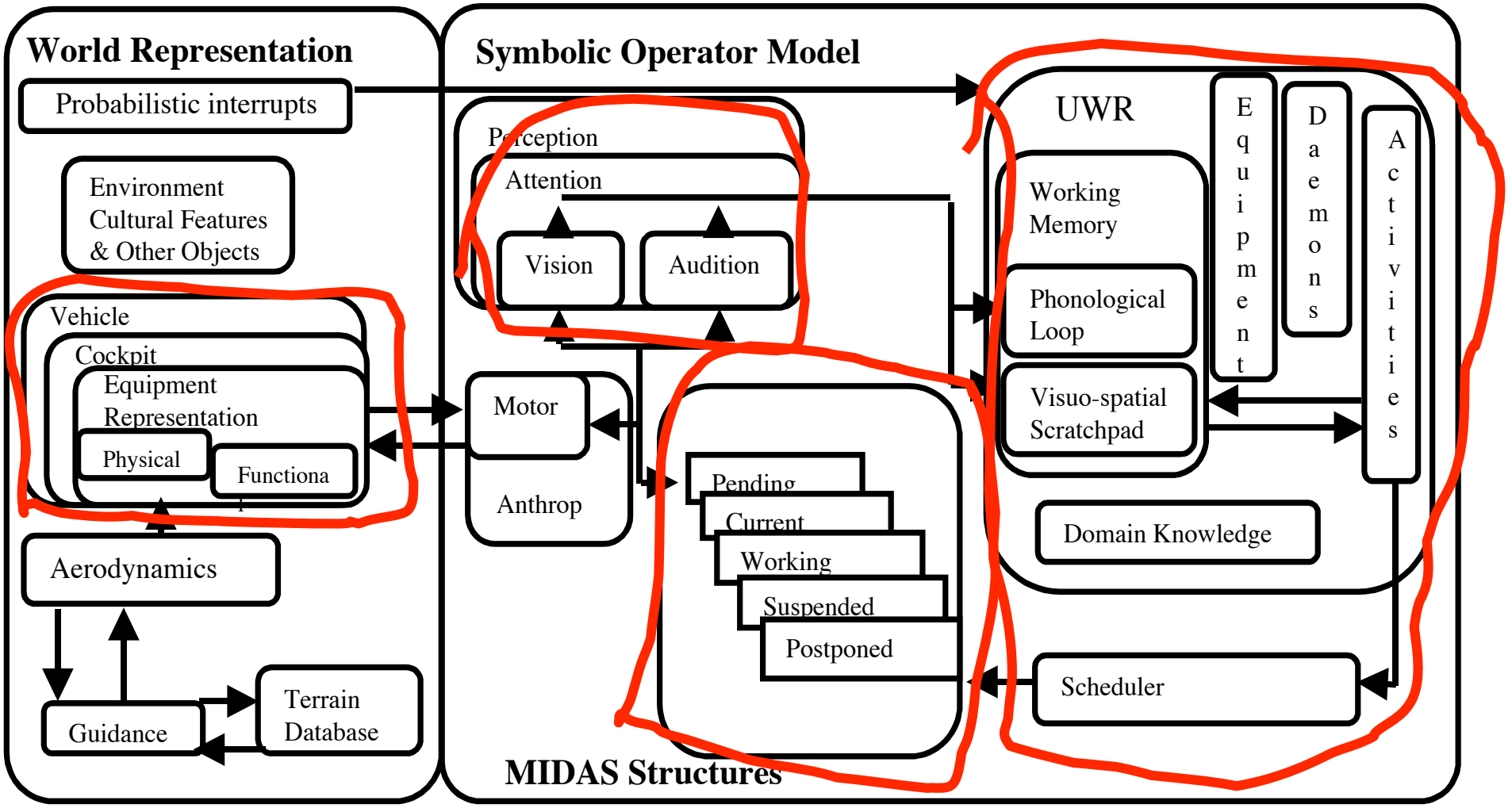
NASA SVS Design Challenge

- Develop augmentative technologies to provide information required for approach and landing under visual minimums
  - Tunnel-in-sky, follow-me aircraft
  - Computer –generated terrain
  - Flight director information
  - Traffic information

Two Studies: Methods of Analyses

- Human in the loop (HITL) processes: NASA & University of Illinois
  - Part task, medium fidelity and full mission
- Human Performance Models (several)
  - Air Midas used to predict the visual sampling and procedural sequences of the pilot flying and the pilot not flying on approach with and without the synthetic vision system

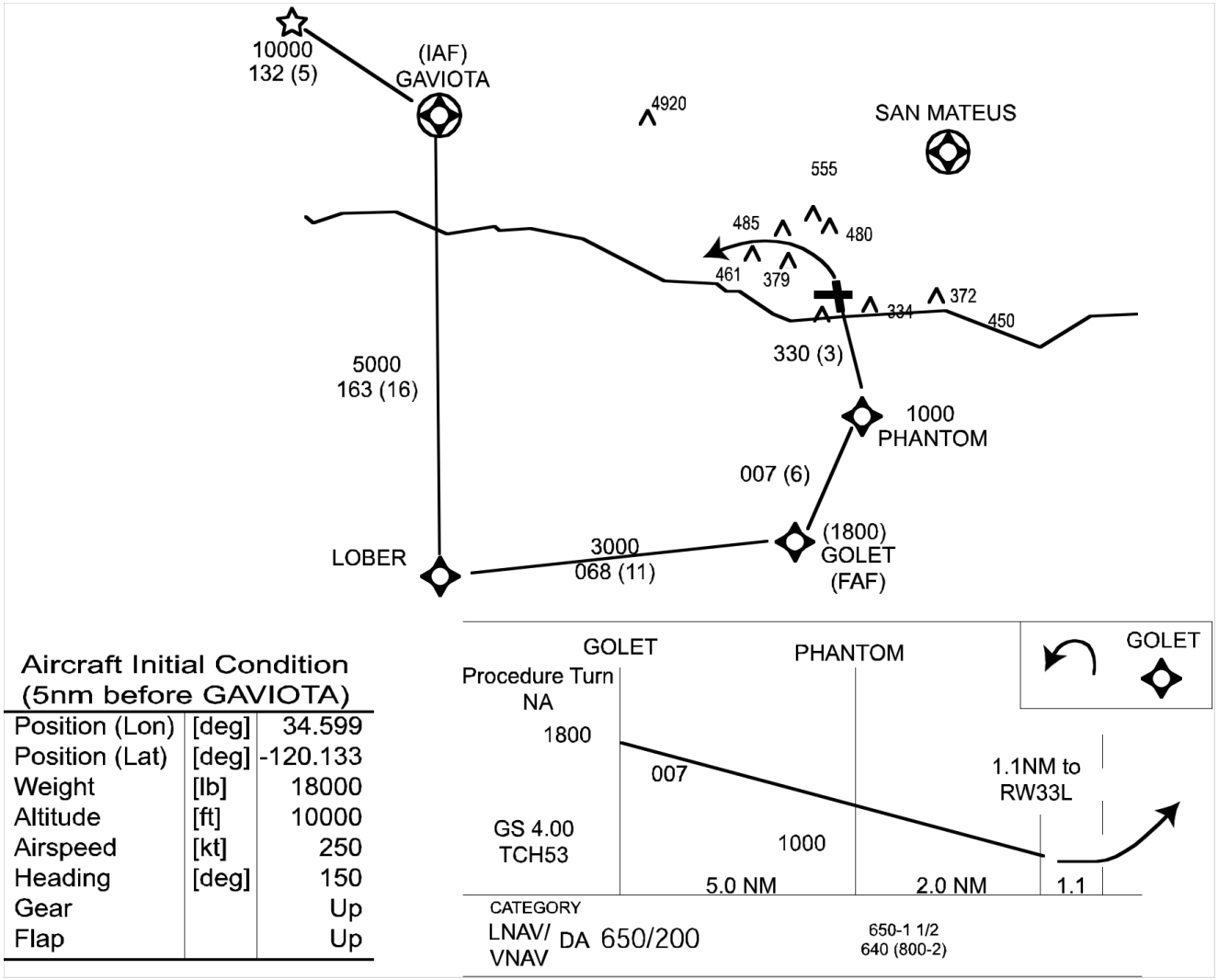
Individual Human Performance Model



Method Study 1

- Calibrate Air Midas Visual Sampling Model
  - Mumaw et al. 2000 Boeing field approach and landing simulation – with standard cockpit instrumentation gps rnav
- Verify model operation running the model on the same approach
- Generalize the model to Santa Barbara approach (new geometry, new procedures)
- Validate Model Output against baseline NASA HITL data
- Generalize the model to use of the SVS on a standard approach and approach with side step.

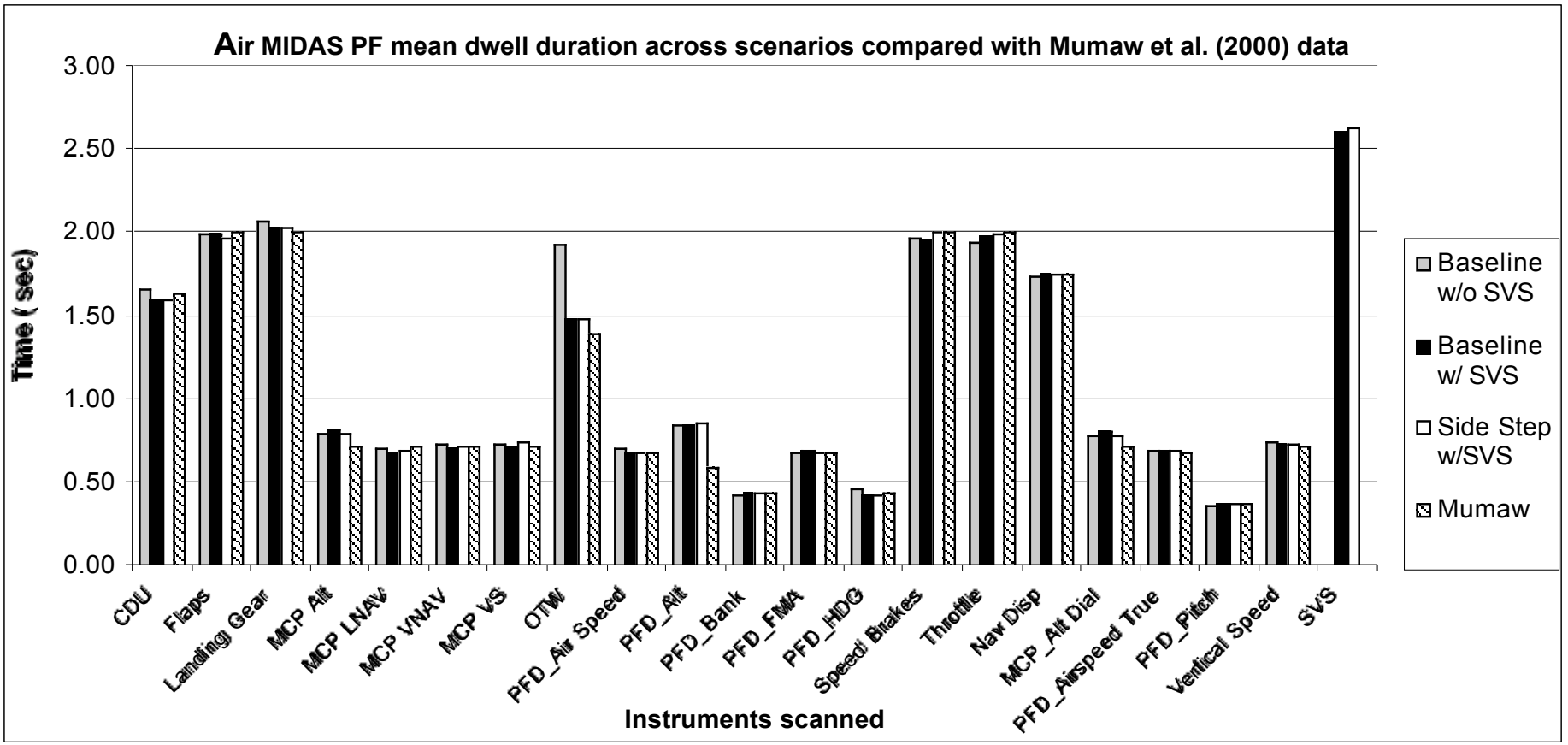
Scenario Region



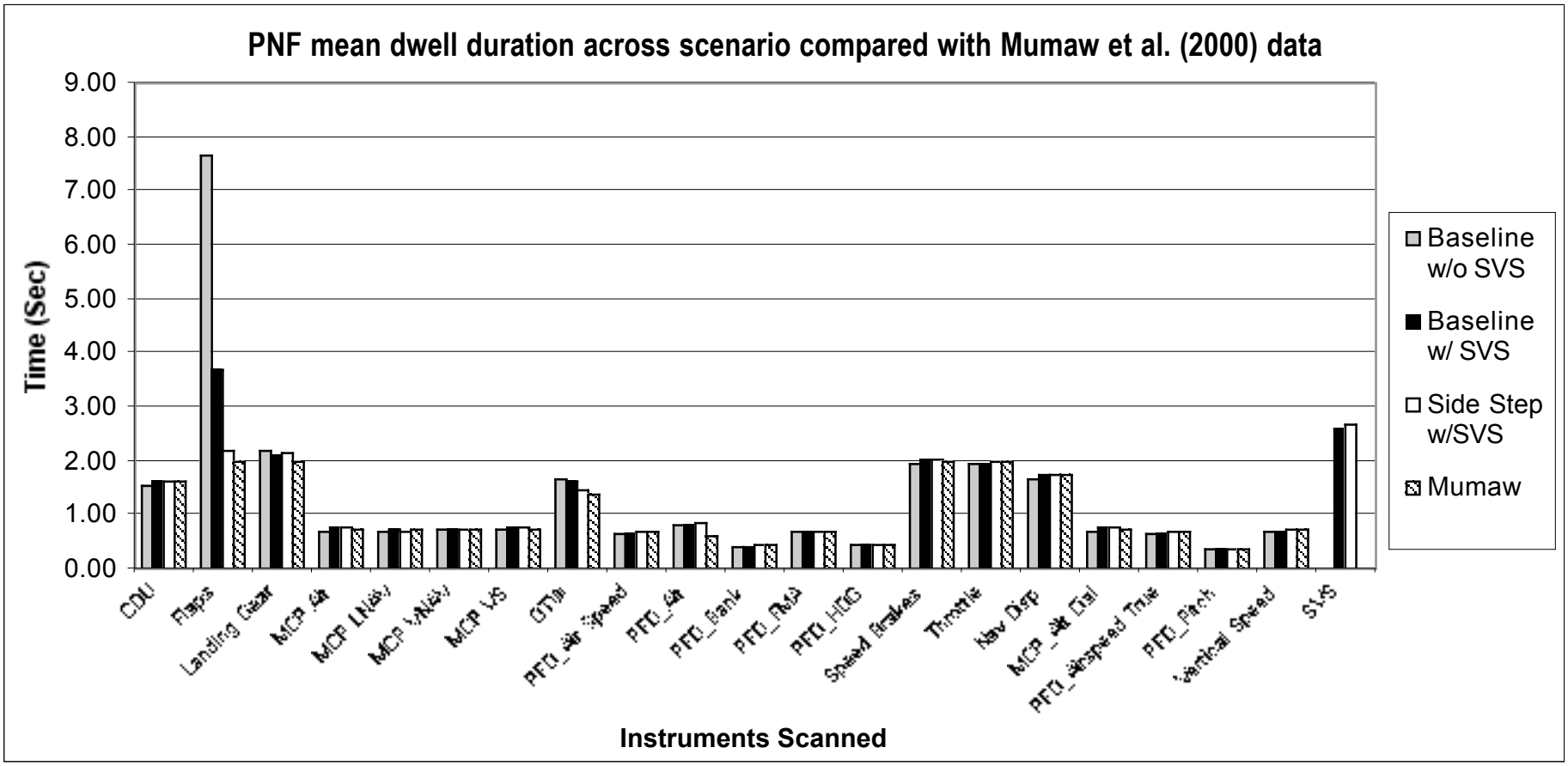
Aircraft Initial Condition
(5nm before GAVIOTA)

Position (Lon)	[deg]	34.599
Position (Lat)	[deg]	-120.133
Weight	[lb]	18000
Altitude	[ft]	10000
Airspeed	[kt]	250
Heading	[deg]	150
Gear		Up
Flap		Up

HPM & Mumaw Results: PF scan pattern



HPM & Mumaw Results: PNF scan pattern



Percent Fixation Correlations[1]

Air MIDAS to Boeing Sim

- Baseline:
  r = 0.9936
- With SVS:
  r = 0.9955
- SVS with sidestep:
  r = 0.9948

Verification

Air MIDAS to NASA Sim

- Baseline:
  r = 0.7608
- With SVS:
  r = 0. 8782
- SVS with sidestep:
  r = 0. 5538

Validation

1: Pearson Product Moment

Scan Data Summary

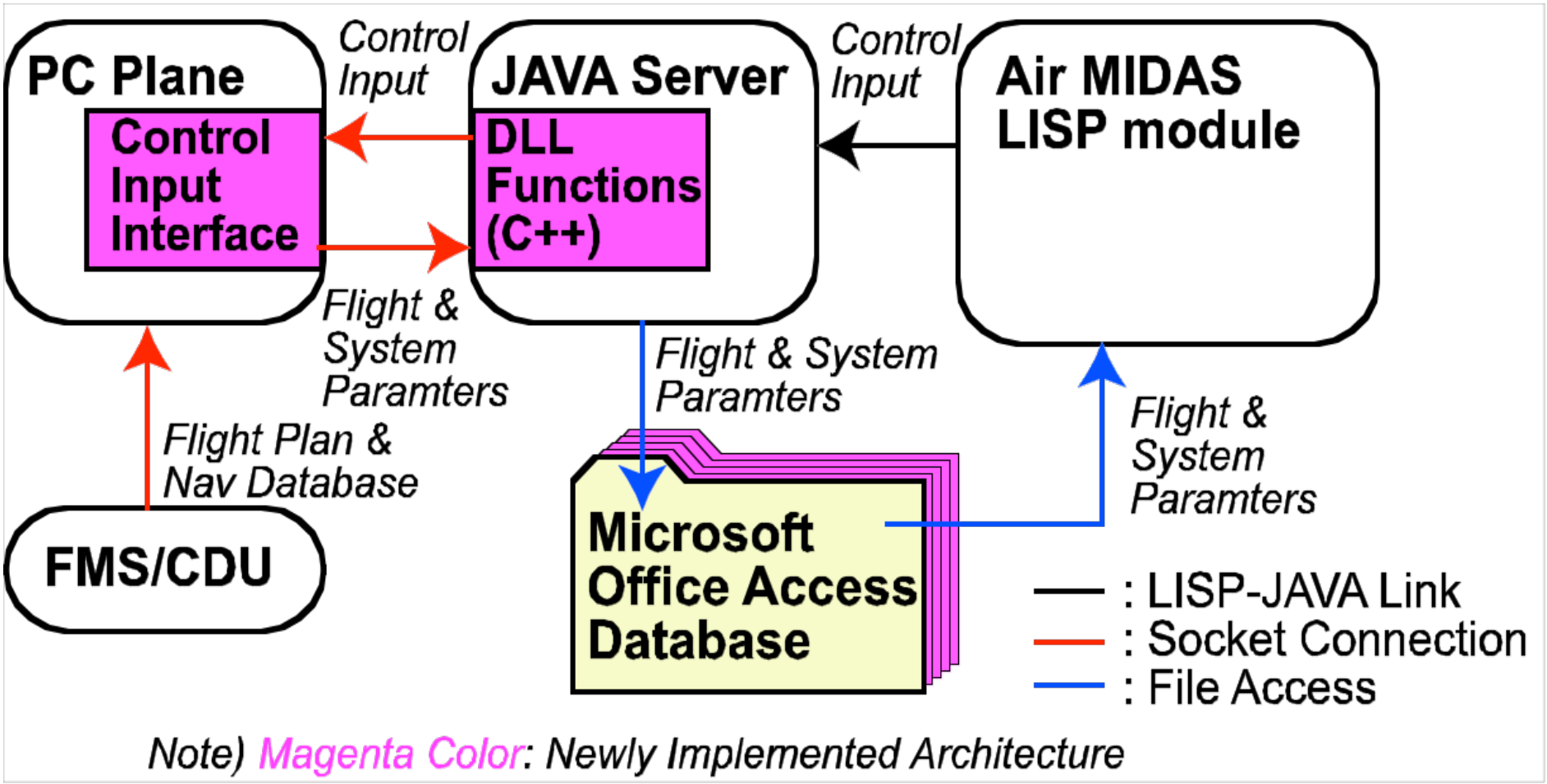
- Human performance model data accurately reproduced the Mumaw et al. (2000) scan patterns and correlated well with the NASA part-task simulation.
- Model behavior is consistent with the human operators' visual scan performance across experimental conditions with the least similarity in the side-step SVS condition.

Method Study 2

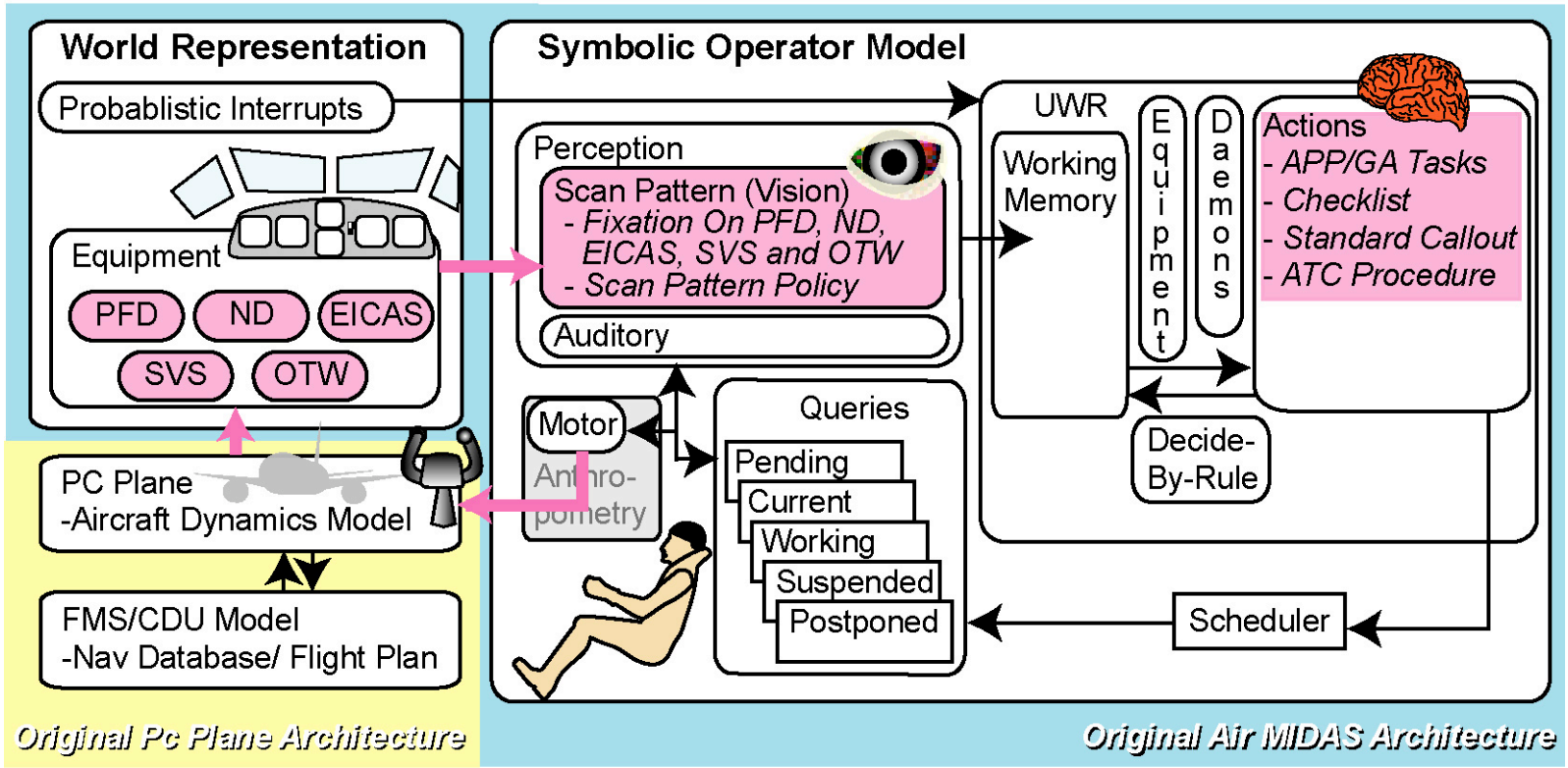
- Use the validated model to explore use of SVS across a range of approach conditions
- Link SVS & Standard Performance to PC Plane
- Fully Crossed Conditions:
  - Normal Approach or Go Around
    - Initiated by ATC call early (700 ft agl) or late (300 ft agl) in high and low workload conditions for the PF & PNF
    - Pilot decision
  - With/without SVS
  - Decision alt 650 ft or 200 ft

Case No.	Approach	SVS	DA (ft)	Weather vis_abv / alt / vis_blw (smi)/(ft)/(smi)	Events	Description	Runs
1	Normal Approach	Without	650	0.5/800/10.0		Base Line	5
2	Normal Approach	With	650	0.5/800/10.0		Base Line	5
3	Normal Approach	Without	200	0.5/350/10.0		DA@200	5
4	Normal Approach	With	200	0.5/350/10.0		DA@200	5
5	Go-Around	Without	650	0.5/800/10.0	ATC GA Com @750ft	GA by ATC	5
6	Go-Around	With	650	0.5/800/10.0	ATC GA Com @750ft	GA by ATC	5
7	Go-Around	Without	200	0.5/350/10.0	ATC GA Com @300ft	GA by ATC	5
8	Go-Around	With	200	0.5/350/10.0	ATC GA Com @300ft	GA by ATC	5
9	Go-Around	Without	650	0.2/650/0.2		GA by Pilot	5
10	Go-Around	With	650	0.2/650/0.2		GA by Pilot	5
11	Go-Around	Without	200	0.2/200/0.2		GA by Pilot	5
12	Go-Around	With	200	0.2/200/0.2		GA by Pilot	5
13	Go-Around	Without	650	0.5/800/10.0	ATC GA Com @900	ATC@HighWL	5
14	Go-Around	With	650	0.5/800/10.0	ATC GA Com @900	ATC@HighWL	5
15	Go-Around	Without	200	0.5/350/10.0	ATC GA Com @450	ATC@HighWL	5
16	Go-Around	With	200	0.5/350/10.0	ATC GA Com @450	ATC@HighWL	5

Air MIDAS System Architecture

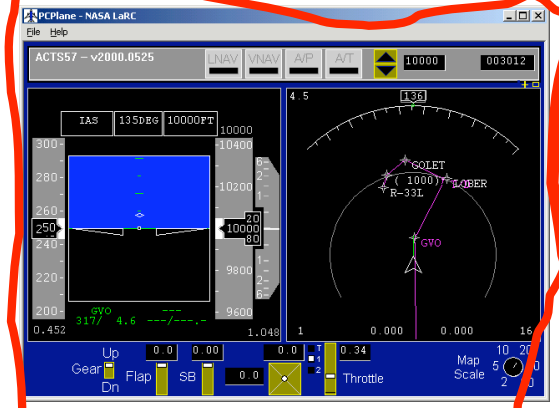


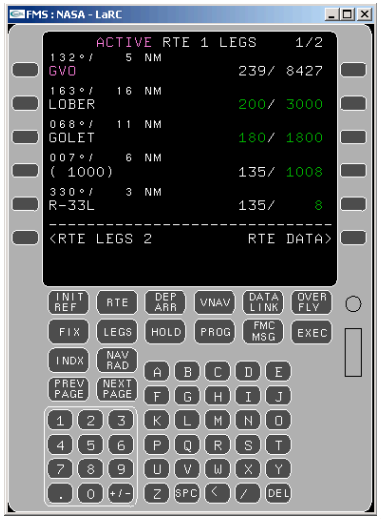
Elaborations on Air MIDAS for Study 2

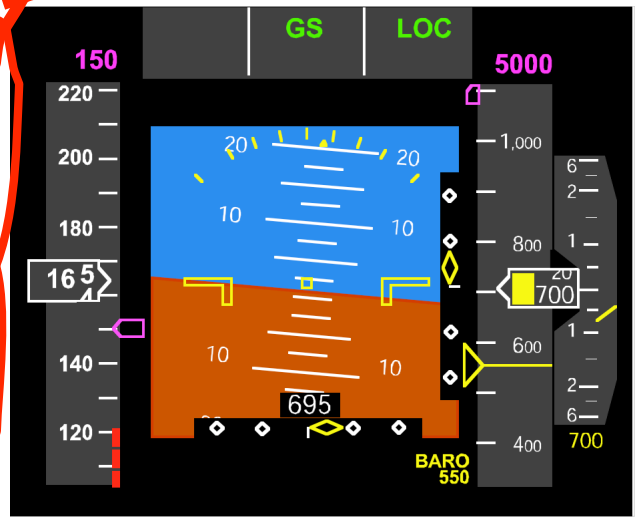


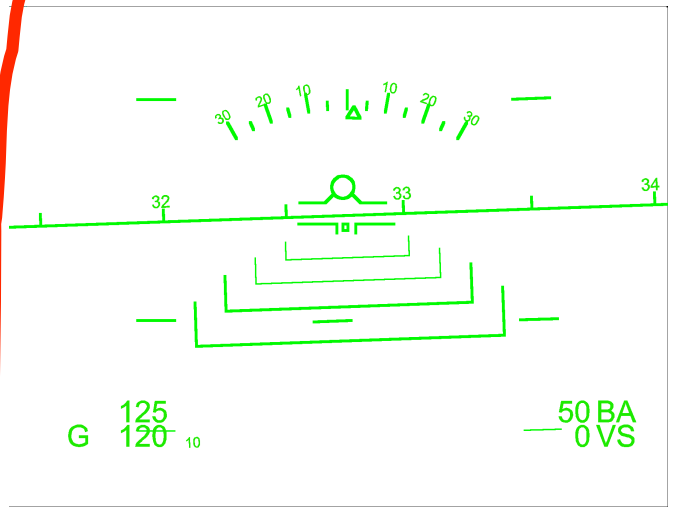
Note: Magenta Color implies Implimentation for SVS application.

Displays

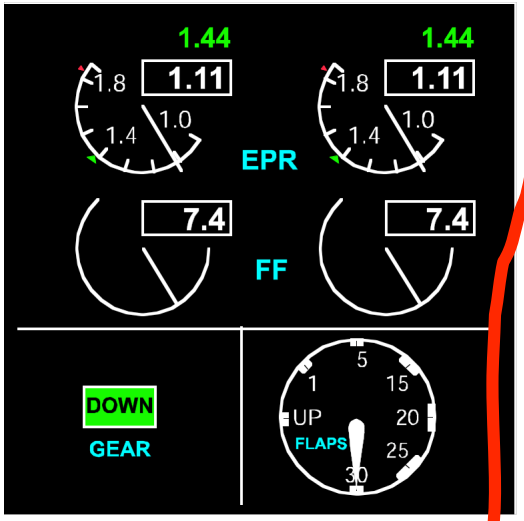

PCPlane - NASA LaRC
File Help
ACTS57 – v2000.0525
LNAV VNAV A/P A/T
10000
003012
IAS
135DEG
10000FT
GOLET
(1000)
R-33L
LOBER
GVO
Up
Gear
Dn
Flap
SB
Throttle
Map
Scale


FMS : NASA - LaRC
ACTIVE RTE 1 LEGS 1/2
132°/ 5 NM
GVO 239/ 8427
163°/ 16 NM
LOBER 200/ 3000
068°/ 11 NM
GOLET 180/ 1800
007°/ 6 NM
(1000) 135/ 1008
330°/ 3 NM
R-33L 135/ 8
<RTE LEGS 2 RTE DATA>
INIT REF
RTE
DEP ARR
VNAV
DATA LINK
OVER FLY
FIX
LEGS
HOLD
PROG
FMC MSG
EXEC
INDX
NAV RAD
PREV PAGE
NEXT PAGE

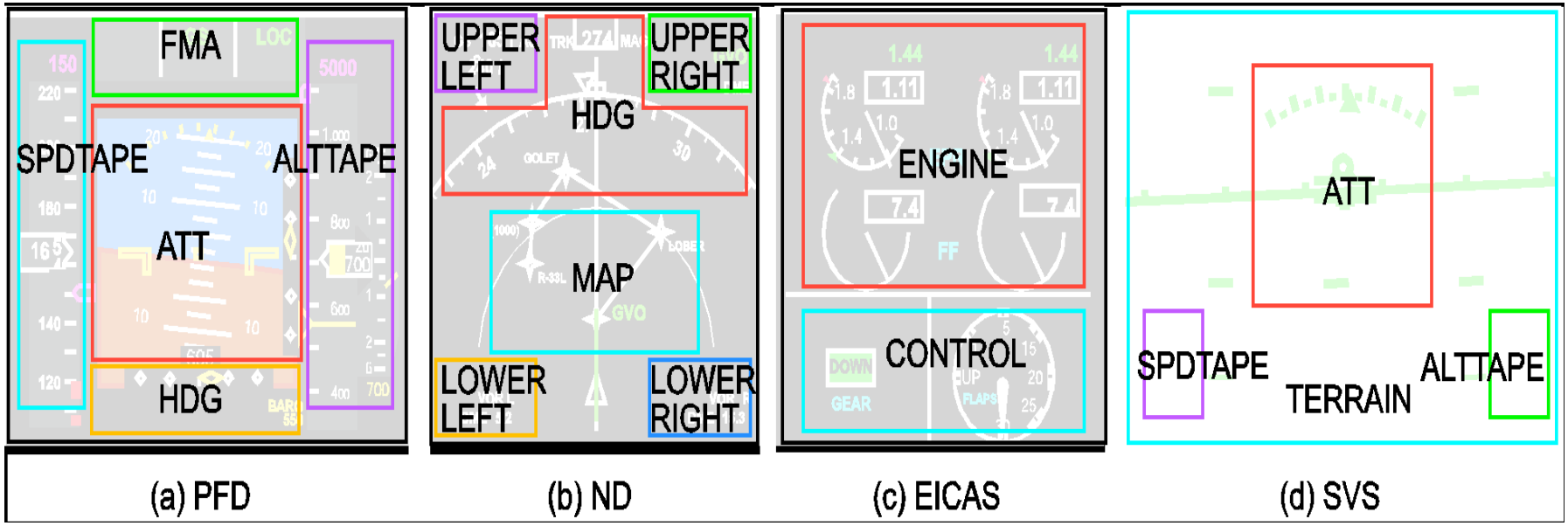

GS
LOC
150
5000
220
200
180
165
140
120
1,000
800
700
600
400
695
BARO
550


32
33
34
125
G 120
10
50 BA
0 VS


GS 165 TAS 165 TRK 274 MAG
240 / 15°
GVO
DME
27
24
30
GOLET
(1000)
R-33L
LOBER
GVO
VOR L
DME 5.2
VOR R
DME 15.3


1.44
1.44
1.8
1.11
1.4
1.0
EPR
7.4
7.4
FF
DOWN
GEAR
UP
FLAPS
5
1
15
20
25
30

Visual Scan Information Sources



Display Information Source

PFD

Parameter	Description	UNIT	VALUE (ex)	AREA
thedg	Pitch Angle	(deg)	5.20	ATT
phidg	Bank Angle	(deg)	10.1	ATT
easkt	IAS	(kt)	213	SPDTAPE
selias	Speed Command	(kt)	200	SPDTAPE
altft	Press. Altitude	(ft)	3,235	ALTTAPE
selalt	Altitude Command	(ft)	3,000	ALTTAPE
roc	Rate of Climb	(fpm)	500	ALTTAPE
apth_e01	Autothrottle Mode		SPD	FMA
appt_e01	Aitopilot Pitch Mode		VNAV	FMA
aprl_e01	Autopilot Roll Mode		LNAV	FMA

ND

Parameter	Description	UNIT	VALUE (ex)	AREA
psidg	Heading Angle	(deg)	276.0	HDG
track	Track Angle	(deg)	269.0	HDG
selhdg	Heading Command	(deg)	300.0	HDG
to_wpt	Name of To Waypoint		GOLET	MAP
rpos_to_dme	DME to To WPT	(nm)	11.2	MAP
rpos_to_brg	Bearing to To WPT	(deg)	125.0	MAP
rpos_tw_dme	DME to Runway	(nm)	20.1	MAP
rpos_rw_brg	Bearing to Runway	(deg)	32.0	MAP

EICAS

Parameter	Description	UNIT	VALUE (ex)	AREA
flap	Flap Angle	(deg)	20.0	CONTROL
nsgear	Gear Position		1	CONTROL
sbrk	Speed Brake Angle	(ratio)	0.1	CONTROL

OTW

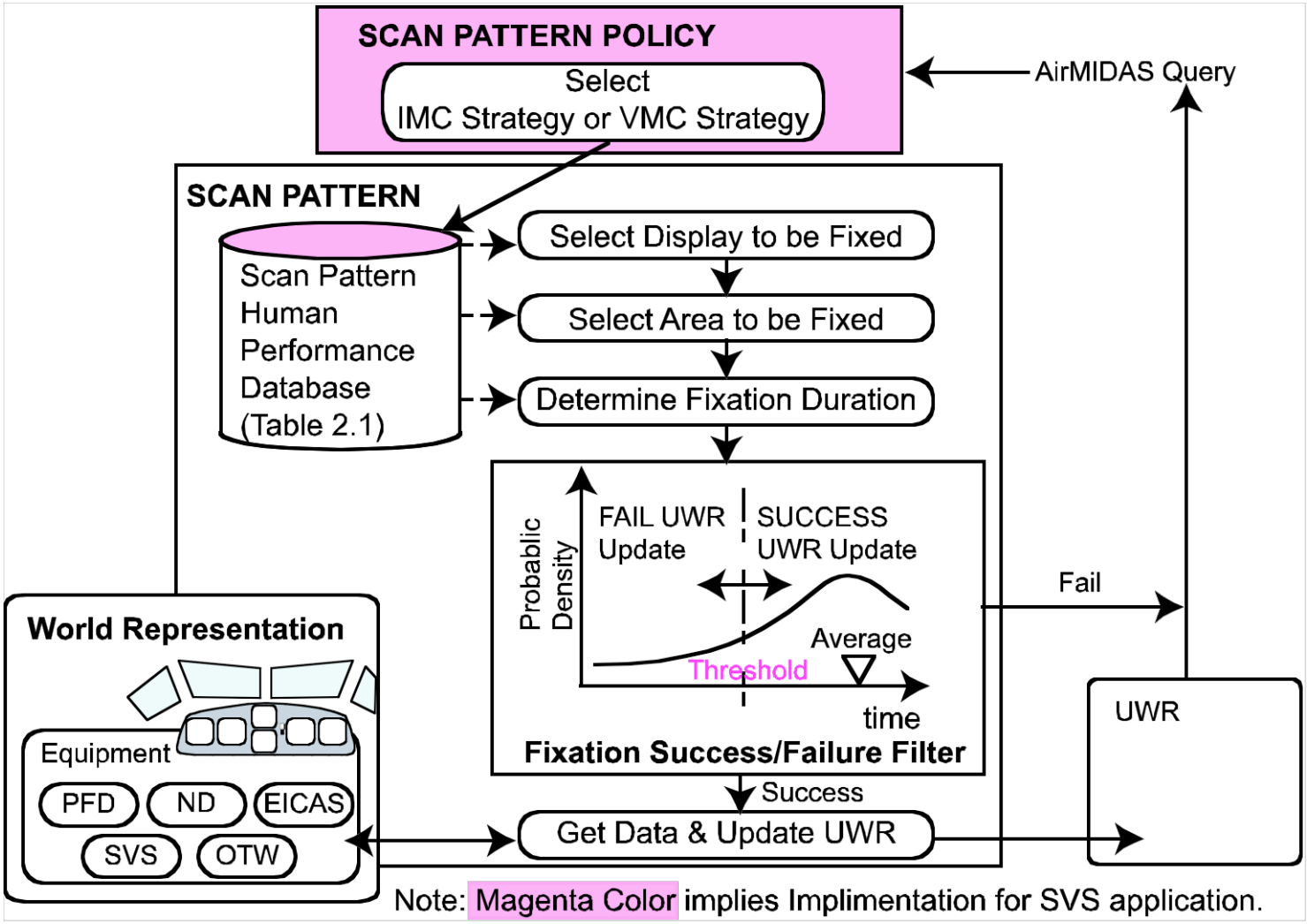
Parameter	Description	UNIT	VALUE (ex)	AREA
thedg	Pitch Angle	(deg)	5.20	ATT
phidg	Bank Angle	(deg)	10.1	ATT
visibility	Visibility	(smi)	5.0	TRR
rpos_tw_dme	DME to Runway	(nm)	20.1	NAV
rpos_rw_brg	Bearing to Runway	(deg)	32.0	NAV

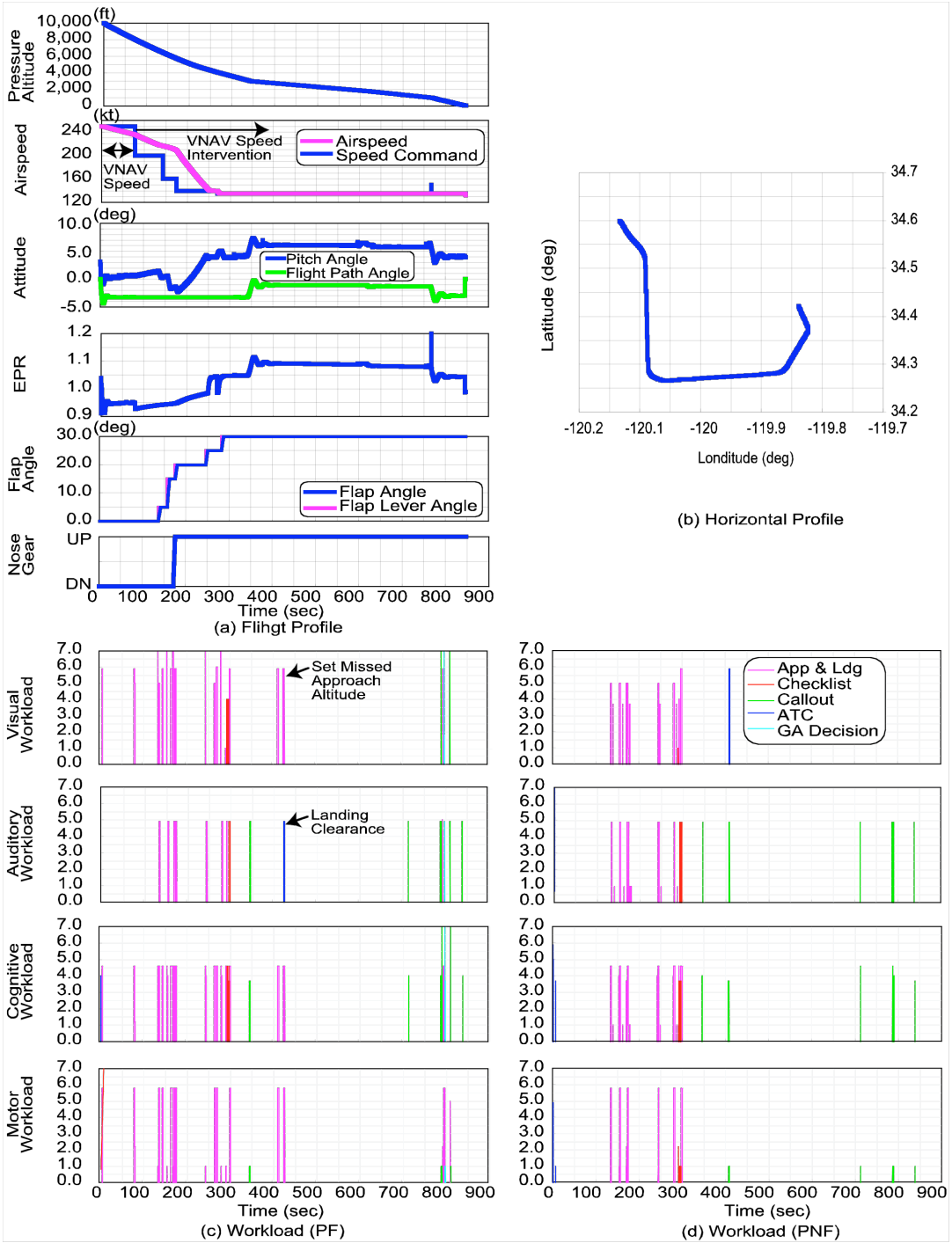
SVS

Parameter	Description	UNIT	VALUE (ex)	AREA
thedg	Pitch Angle	(deg)	5.20	ATT
phidg	Bank Angle	(deg)	10.1	ATT
easkt	IAS	(kt)	213	SPDTAPE
selias	Speed Command	(kt)	200	SPDTAPE
altft	Press. Altitude	(ft)	3,235	ALTTAPE
selalt	Altitude Command	(ft)	3,000	ALTTAPE
roc	Rate of Climb	(fpm)	500	ALTTAPE
rpos_tw_dme	DME to Runway	(nm)	20.1	OTW
rpos_rw_brg	Bearing to Runway	(deg)	32.0	OTW

Note) Altitude and Speed on SVS was not used for the trigger of procedural tasks.

Scan Pattern Policy





Normal Approach

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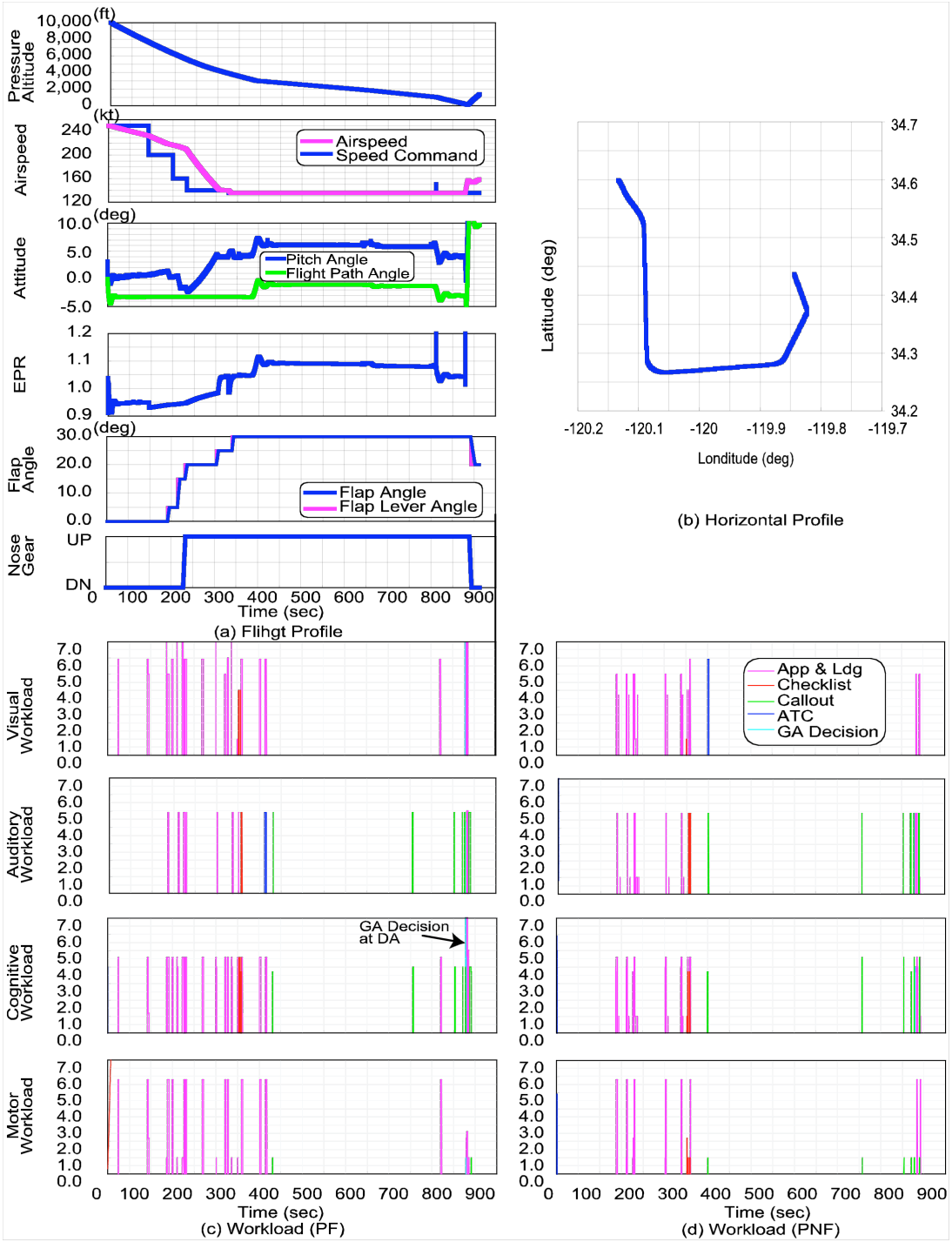
Ames Research Center

Go Around Pilot's Decision



Conclusions

- SVS would not adversely affect the flight safety in approach, landing and go-around phase regardless of decision altitude and triggers of go-around including PF's intention at decision altitude and ATC's command, while it would allow approach and landing in conditions that would otherwise be unattainable.
- Small delays of action initiation in flight control were observed in approach phase with SVS operation. This occurred because that the chances of fixation on each display was decreased by adding SVS to conventional display configuration,
- No human performance degradation and no delay of task initiation were observed in landing and go around phase, though there were time shifts in the approach phase.
- A scan pattern model which simulates pilot's instrument scan was validated by using the data of human-in-the-loop simulation. Sensitivity analysis on threshold setting for information acquisition failure model was performed and (mean-1.0SD) fixation duration was selected for the threshold of failure occurrence so that the error rate of scan perception was 10% or less.

Concluding Remarks

- SVS as advisory system is presumed to augment the flight crew situation awareness and thus improve decision making and reduce load
- Human performance model as run has no formal mechanism to represent a “situation” though it does represent the information state of the PF & PNF
- Build abstraction that is a “situation” composed of information elements and structured to support the Endsley functions current and future state projections